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**JAMES EDWARD KEELER.**

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JAMES EDWARD KEELER.

The Lick Observatory has lost an ideal Director. Astronomy has suffered a loss it can ill afford. Colleagues and friends widespread will miss a companionship which was simply delightful.

JAMES EDWARD KEELER was born in La Salle, Illinois, on September 10, 1857. RALPH KEELER, his first American ancestor, settled in Hartford in 1635. His father, WM. F. KEELER, was an officer of the original *Monitor* at the time of its engagement with the *Merrimac*. His mother (still living) is the daughter of HENRY DUTTON, former Governor of Connecticut, and Dean of the Yale Law School.

In 1869 the family removed from La Salle, Illinois, to Mayport, Florida. Here KEELER prepared for college under the tutelage of his father and his older brother. Here his fondness for astronomical studies was developed. He established "The Mayport Astronomical Observatory" in 1875-77. It included, at the least, a quadrant, a two-inch telescope, a meridian-circle, and a clock. Under date of 1875, September 22d, his journal records an observed altitude of *Polaris*, secured with "my quadrant." Other entries read:—

"1875, Nov. 14.—Sent to Queen last night for lenses for my telescope."

"1875, Nov. 29.—Lenses from Queen came to-night; one two-inch achromatic, and two plano-convex lenses for eye-piece."

"1875, Dec. 12.—Directed my telescope to the stars, and saw the rings of *Saturn* for the first time. . . ."

"Dec. 14.—Saw the Annular Nebula in *Lyra*. One satellite of *Saturn*. . . . All four of the stars in the Trapezium. . . ."

"1876, Jan. 26.—Got up at  $\frac{1}{2}$  past 4 this morning and applied my telescope to *Jupiter* for the first time. . . ."

In 1877, at the age of twenty years, he constructed a meridian-circle instrument. The telescope of it was that of a common spy-glass, 1.6-inch aperture, and 13.45-inch focus. The axis was turned out of wood. Brass ferrules driven on the ends of the axis, and turned down, formed the pivots. The wooden circle, 13.3 inches in diameter, was graduated to 15'. KEELER's original sketch of this instrument, and his written description of it, are published elsewhere in this number of the *Publications*.

His "Record of Observations, made at the Mayport Observatory," contains beautiful colored sketches of *Jupiter*, *Saturn*, *Venus*, *Mars*, the *Orion Nebula*, of double stars, and of "Scenery on the Moon"; and in addition, data of a numerical character. These early drawings are characterized by the refined taste and skill so well known from his later professional work.

Mr. KEELER entered Johns Hopkins University late in 1877; and, following major courses in Physics and German, he was graduated with the degree of A. B. in 1881. At the end of his freshman year, he accompanied Professor HASTINGS, as a member of Professor HOLDEN's party from the Naval Observatory, to observe the total solar eclipse of July 29, 1878, at Central City, Colorado. Although his part was the modest one of making a drawing of the corona, his written report on the work is a model scientific paper, and may be read with profit by visual observers of eclipses.

In the spring of 1881, Professor LANGLEY, desiring an assistant in the Allegheny Observatory, requested the Johns Hopkins University to recommend a suitable man for the place. KEELER was named for and accepted the appointment, beginning work at Allegheny several weeks before receiving his degree. I was speaking, in June of this year (1900) with one of the physicists who had recommended KEELER for the Allegheny position, and the subject of this very appointment came up. "I told Professor LANGLEY," said he, "that one of my strongest reasons for the recommendation is that KEELER does n't claim to know everything." To the end of his life, this charming trait remained unimpaired. It is to KEELER's credit that he largely defrayed his own expenses in college by acting as assistant to some of the lecturers in the experimental courses.

Professor LANGLEY made his noted expedition to the summit of Mt. Whitney, California, in June-September, 1881, to determine the value of the "Solar Constant." Mr. KEELER accom-

panied the expedition in the capacity of assistant, and carried out his share of the programme with skill and efficiency. Returning at once to Allegheny, his work until May, 1883, was closely related to the many problems arising from the Mt. Whitney expedition.

The year 1883-4 was devoted to study and travel abroad. The months of June, July, and August, at Heidelberg, were given to the study of Light and Electricity under QUINCKE, Chemistry under BUNSEN, and Integral Calculus under FUCHS. During the winter semester, in Berlin, he heard the lectures on Physics by HELMHOLTZ and KAYSER, on Differential Equations by RUNGE, and on Quaternions by GLAN. His main investigation in the physical laboratory was on "The Absorption of Radiant Heat by Carbon Dioxide," — a problem suggested no doubt by his Mt. Whitney experiences.

From June, 1884 to April, 1886, Mr. KEELER again served as assistant in the Allegheny Observatory, affording most efficient help to Professor LANGLEY in his classical researches on the lunar heat, and on the infra-red portion of the solar spectrum.

Early in 1886, on Professor HOLDEN's recommendation, Mr. KEELER was appointed Assistant to the Lick Trustees. He arrived at Mt. Hamilton on April 25, 1886, and immediately proceeded to establish the time service. The telegraph line to San José was perfected, the transit instruments, the clocks, and the sending and receiving apparatus at both ends of the line, were installed. The signals were sent out on and after January 1, 1887; north to Portland, east to Ogden, and south to San Diego and El Paso. In addition to the time service, he assisted the Trustees in installing the various instruments.

When the Observatory was completed, and transferred to the Regents of the University of California, on June 1, 1888, Mr. KEELER was appointed Astronomer; the original staff consisting of Astronomers HOLDEN, BURNHAM, SCHAEBERLE, KEELER and BARNARD, and Assistant Astronomer HILL.

Professor KEELER was placed in charge of the spectroscopic work of the Observatory. The large star spectroscope, constructed mainly from his designs, has no superior for visual observations. Of the many results obtained with this instrument we may mention the observations of *Saturn's* rings and *Uranus*, with reference to their atmospheres; of the bright and dark lines in the spectra of  $\gamma$  *Cassiopeiæ* and  $\beta$  *Lyræ*; of the color curve of

the 36-inch equatorial; and of the spectra of the *Orion Nebula* and thirteen planetary nebulae.

His beautiful observations on the velocities in the line of sight of these fourteen nebulae mark a distinct epoch in visual spectroscopy. His memoir on the subject took its place as a classic at once. The probable error of the final result for each nebula, based on the mean of several observations, is only  $\pm 3.2$  kilometers per second. Attention should be called to one extremely important fact established by these measures, viz: the velocities of the nebulae in their motion through space are of the same order of magnitude as the velocities of the stars.

The recognition of the fact that a great refracting telescope is also a most powerful spectroscope for special classes of objects, by virtue of the chromatic aberration of the objective, is due to Professor KEELER. Among the first objects observed with the 36-inch equatorial were the planetary nebulae and their stellar nuclei. The observers were struck with the fact that the focal length for a nebula is 0.4 inch longer than for its stellar nucleus; a discrepancy which Professor KEELER at once explained by recalling that the star's light is yellow, whereas that of the nebula is greenish-blue.

Astronomical readers will remember KEELER's splendid drawings of the planets *Saturn*, *Jupiter*, and *Mars*, made with the assistance of the 36-inch telescope, during 1888-90. His faithful and artistic drawings of *Jupiter* have no equal.

He was in charge of the very successful expedition sent by the Lick Observatory to Bartlett Springs, California, to observe the solar eclipse of January 1, 1889.

Professor KEELER resigned from the Lick Observatory staff on June 1, 1891, to succeed Professor LANGLEY as Director of the Allegheny Observatory and Professor of Astrophysics in the Western University of Pennsylvania. The Allegheny Observatory has perhaps the poorest location of any observatory in this country for spectroscopic work. But in spite of this disadvantage, KEELER's investigations continued and promoted the splendid reputation established for the observatory by his predecessor. He comprehended the possibilities and limitations of his situation and his means, and adapted himself to them. His spectroscopic researches were largely confined to the orange, yellow, and green regions of the spectrum, since these would be less strongly affected by the smoky sky, for which that vicinity is famous.

The Allegheny spectroscope, designed and constructed soon after his acceptance of the position, contained several valuable improvements. The use of three simple prisms in its dispersive train was a departure which has been followed with great advantage in many later instruments. With this instrument he made an extensive investigation of the *Orion Nebula* and the stars immersed in it, establishing the fact that the nebula and the stars are closely related in physical condition.\* His beautiful observations of *Saturn's* rings, proving that they are a cluster of meteorites — myriads of little moons — have never been surpassed in interest in the entire astronomical field. These observations are so well known to every one interested in astronomy that a single sentence suffices. He proved spectrographically, using the Doppler-Fizeau principle, that every point in the ring system is moving with the velocity which a moon would have if situated at that distance from the planet. Professor KEELER's main piece of work at the Allegheny Observatory, on the spectra of the third (Secchi) type stars remains unpublished, but the measures and reductions are left in an advanced stage.

The Regents of the University of California appointed Professor KEELER to the position of Director of the Lick Observatory on March 8, 1898. The ties which bound him and his family to Allegheny were difficult to sever; but the greater opportunities offered by the instruments and the atmospheric conditions at Mt. Hamilton decided him in favor of accepting the appointment. He entered upon his new duties on June 1, 1898.

Without making any rearrangement of the work of the staff, but affording them every possible encouragement to continue along the same lines, Professor KEELER arranged to devote his own observing-time to the Crossley reflector. He recognized that the instrument was not in condition to produce satisfactory results. He made one change after another, overcoming one difficulty after another, until, on November 14th, he secured an excellent negative of the *Pleiades*, and on November 16th, a superb negative of the *Orion Nebula*. The enormous power of the reflector in nebular photography was established, and he entered upon the programme of photographing all the brighter nebulae in HERSCHEL's catalogue. More than half of the subjects on the programme have been completed. The Observatory

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\* Simultaneous observations of the same object made at another observatory led to the same conclusion.

possesses a set of negatives of the principal nebulae which is priceless and unequaled. These photographs have already led to many discoveries of prime importance; and they furnish a vast amount of material for future investigations of questions bearing especially upon the early stages of sidereal evolution. The photographs record, incidentally, great numbers of new nebulae; as many as thirty-one on a single plate covering less than one square degree of the sky. A conservative estimate places the number within reach of the Crossley reflector at 120,000, of which only ten or fifteen thousand have thus far been discovered.

It has previously been supposed that the great majority of nebulae are irregular and without form, and that only a few are spirals. Professor KEELER's photographs have recorded more spiral nebulae than irregular ones. This discovery bears profoundly on the theories of the cosmogony, and must be considered as of the first order.

It is time to refer to Professor KEELER's work as Director. I but faintly reflect the views of every member of the staff, and indeed of all who have been interested in the work of this Observatory, when I say that his administration was completely successful. He cherished and promoted ideal conditions in this ideal place. He made a success of his own work, in a splendidly scientific manner; and he saw to it that every one had all possible opportunities to do the same. No member of the staff was asked to sacrifice his individuality in the slightest degree. Nor were demands made for immediate results. No one's plans were torn up by the roots to see if they were growing. The peace of mind of the investigator, so absolutely essential for complete success, was full and undisturbed. Withal, Professor KEELER's administration was so kind and so gentle, and yet so effective, that the reins of government were seldom seen and never felt.

The elements of his successes are simple, and plainly in view. His openness and honesty of character, his readiness and quickness to see the other man's point of view, his strong appreciation of the humorous, as well as the serious, and above all his abounding good sense,—these traits made his companionship delightful and charming. Scientifically, Professor KEELER never groped aimlessly in the dark. He would not attack a problem until he had as fully as possible comprehended its nature, and the requirements for success. With the plan of attack completely considered, and the instruments of attack at hand, the execution of his



plans involved little loss of time. The Crossley reflector affords a case in point. Assisted by a Fellow in Astronomy and by the instrument-maker, he devoted five months to preparing the reflector for turning out the magnificent results which *at once* followed.

Professor KEELER's published papers have a finish and a ripeness which are rarely seen. His love of the beautiful and his artistic skill are evident in all his work.

To speak of the people who had afforded him encouragement at different times in his life, was one of his pleasures. His father's friend, Mr. CHAS. H. ROCKWELL, of Tarrytown, was constant in urging the development of so promising a career. He did not forget Professor HASTINGS' continual kindness and interest during his college days. He frequently spoke of the great value of Mr. WILLIAM THAW's interest and encouragement, both to himself and to the Allegheny Observatory; an interest which was continued after Mr. THAW's death by other members of Mr. THAW's family.

The honorary degree of Sc. D. was conferred upon Professor KEELER in 1893 by the University of California. He received the Rumford medal from the American Academy of Arts and Sciences in 1898, and the Henry Draper medal from the National Academy of Sciences in 1899. He was a member of the National Academy of Sciences; an Associate of the American Academy of Arts and Sciences; a Fellow and Foreign Associate of the Royal Astronomical Society; a Fellow of the American Association for the Advancement of Science; a member and officer of the Astronomical and Astrophysical Society of America; an honorary member of the Toronto Astronomical and Physical Society; the President of the Astronomical Society of the Pacific; a member of the Washington Academy of Sciences, and various other organizations.

It appears that Professor KEELER had long been a sufferer from a mild form of heart weakness; to run even fifteen steps caused him great physical distress. It is feared that on Mt. Hamilton he worked beyond his strength. His weakness seemed to develop rapidly this summer. He went away from the Observatory on July 30th, in the best of spirits, and with no anxiety, to secure medical treatment, and to spend a brief vacation in the northern part of the State. Increasing difficulty in breathing led him to seek skilled treatment in San Francisco, on August 10th.

His dangerous condition was recognized on August 11th, and on the 12th a stroke of apoplexy proved fatal.

When the dangerous weakness of his heart was discovered by the physicians, Professor KEELER's main regret was that he would have to leave Mt. Hamilton and its opportunities, in order to live at a lower altitude. It is known that he had planned his work with the Crossley reflector far into the future. A small spectrograph which he was most anxious to employ on certain interesting spectra was completed on the day of his leaving the Observatory.

The absence of one so old in experience and so ripe in judgment will be seriously felt throughout his profession.

Professor KEELER married Miss CORA S. MATTHEWS at Oakley Plantation, Louisiana, on June 16, 1891. Of her great sorrow, and of the grievous loss to the two children, it would be futile to speak.

W. W. CAMPBELL.

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## THE CROSSLEY REFLECTOR OF THE LICK OBSERVATORY.\*

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By JAMES E. KEELER.

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The Crossley reflector, at present the largest instrument of its class in America, was made in 1879 by Dr. A. A. COMMON, of London, in order to carry out, and test by practical observation, certain ideas of his respecting the design of large reflecting telescopes. For the construction of the instrument embodying these ideas, and for some fine astronomical photographs obtained with it, Dr. COMMON was awarded the gold medal of the Royal Astronomical Society in 1884.

In 1885, Dr. COMMON, wishing to make a larger telescope on a somewhat similar plan, sold the instrument to EDWARD CROSSLEY, Esq., F. R. A. S., of Halifax, England. Mr. CROSSLEY provided the telescope with a dome of the usual form, in place of the sliding roof used by its former owner, and made observations with it for some years; but the climate of Halifax not being

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\* Reprinted from the *Astrophysical Journal* for June, 1900.